# WEATHER INFLUENCES ON NOCTURNAL BIRD MORTALITY AT A NORTH DAKOTA TOWER

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Most studies of bird losses at towers have dealt with weather conditions in a general manner (e.g. Tordoff and Mengel 1956, Kemper 1959, Taylor and Anderson 1973) because losses usually were not monitored on a daily basis throughout the entire migration season. Thus, weather conditions prevailing on nights of large, spectacular kills have received the most attention. Such nights are usually characterized by overcast skies, often with precipitation, winds favorable for migration, and in the fall the passage of cold fronts (e.g. Brewer and Ellis 1958).

In the course of a study of bird migration and mortality at the U.S. Coast Guard's Omega Navigation Station, located approximately 3 km west of LaMoure, North Dakota in the James River Valley (Avery et al. 1975), it was apparent that while occasional large kills occurred on overcast nights, considerable losses took place throughout the migration seasons under non-overcast skies, particularly in the spring. Since mortality was monitored daily and accurate weather data were available from nearby, it was possible to analyze the losses with respect to cloud cover and wind conditions during 4 entire migration seasons.

## METHODS

The 366-m Omega tower is supported by 3 sets of 5 guy wires (34.9–60.3 mm diameter) spaced 120° apart. The guy wires are attached at heights of 53, 109, 167, 228, and 293 m. The lower 2 guys are anchored 122 m from the tower, the next 2 at a distance of 213 m, and the last at 297 m. In addition, 16 evenly spaced transmitting cables (50.8 mm diam.) extend from the top of the tower to a circular perimeter road 732 m away.

Searches for tower casualties were made every morning at daybreak (except for 7 days) during the study periods: 30 March–4 June and 8 August–15 November 1972 and 2 April–2 June and 12 August–3 November 1973. Because the size of the tower site and the dense vegetation on it made it difficult to find all bird casualties, the area under the guy wires (approximately 168 ha) was divided into 4 concentric strata (Avery et al. 1975): A, 0–46 m (0.66 ha) from the tower; B, 47–92 m (1.97 ha); C, 93–183 m (7.88 ha); and D, 184–732 m (157.61 ha). During the daily searches, stratum A was checked completely. The approximate areas searched in the other strata were: B—0.37 ha (18.8%), C—0.50 ha (6.3%), and D—1.51 ha (1.0%). The location and condition of each bird were recorded as it was collected, and only specimens judged to have died during the previous night were included in the analyses presented here, unless stated otherwise.

Because official weather data are not available from LaMoure, hourly weather reports were obtained from the Federal Aviation Administration Flight Service Station at Jamestown, 72 km north-northwest of LaMoure. A few of the records were discarded inadvertently by the station prior to analysis; thus, cloud cover and wind data are not available for these nights. Each of the 225 nights for which we have records of cloud cover was characterized as overcast or non-overcast. Four classes of cloud cover are recognized in the official weather reports—$< 0.1$ sky cover, 0.1 to $< 0.6$, 0.6 to 0.9, and $> 0.9$. These were assigned the numbers 0, 1, 2, and 3, respectively, and the 13 hourly figures from 1800–0600 CST were summed. The mean was calculated and a night was designated overcast if the mean was $\geq 2.5$. All other nights were called non-overcast. This distinction is somewhat arbitrary and, conceivably, if different criteria were used, slightly different interpretations of the data would result. Wind direction and estimates of cloud cover made at the Omega tower corresponded well with the official weather reports from Jamestown.

The mean, nightly, surface wind direction was calculated from the hourly records; and the mean directions were grouped into four 90° sectors. Nocturnal bird migration in this region is primarily along a northwest-southeast axis (Richardson and Gunn 1971, Avery et al. 1976), and in this paper winds are referred to as favorable if from the 106°–195° quadrant on spring nights and 286°–015° on fall nights.

Losses in the 3 most frequently killed families, Rallidae, Parulidae, and Fringillidae, were examined during their respective periods of peak migration as indicated by field surveys conducted several times weekly near the tower site. Only the losses on nights within each of these peak migration periods were used in these analyses. Chi-square goodness-of-fit tests were used to determine if, within each family, the losses occurring during the entire peak periods in each cloud-wind category were in the same proportions as the number of nights in those categories. The G-test (Sokal and Rohlf 1969) was used to ascertain independence between cloud cover and distance of kill from the tower (Table 4) and between cloud cover and season (Table 5). Prior to analysis, the data used in Tables 4 and 5 were corrected for differences in the area searched in each stratum. In all tests $p \leq 0.05$ was accepted as statistically significant.

## RESULTS AND DISCUSSION

The 5, largest, single-night kills and the accompanying weather conditions are listed in Table 1. All occurred under an overcast sky with the exception of the night of 14–15 May 1972 which was moonless and clear. Weather data revealed no conditions of overcast or poor visibility anywhere in the region that night. The behavior of birds at the tower during the kills on overcast nights was generally similar to that described by previous authors (e.g. Cochran and Graber 1958) and is treated in more detail in another paper (Avery et al. 1976).

Although the largest collections of dead and injured birds were made following overcast nights, mortality occurred consistently on clear nights as well. Table 2 shows that during spring migration the percent of losses of rails and fringillids occurring on overcast nights was about the same as the rate of occurrence of those nights; however, spring mortality in warblers and fall mortality among all 3 families occurred on overcast nights in greater-than-expected percentages ($p \leq 0.05$).

During their peak periods of spring migration, rails and fringillids were

TABLE 1

THE 5 LARGEST SINGLE-NIGHT LOSSES AT THE OMEGA TOWER IN 1972 AND 1973

| Night of kill | Birds found | Weather conditions during night |
|---|---|---|
| 25–26 Sept. 1973 | 69 | overcast, light rain, light ENE wind |
| 4– 5 Oct. 1972 | 48 | overcast, NE wind 5–15 k |
| 14–15 May 1972 | 27 | clear, light S wind |
| 10–11 May 1972 | 25 | overcast, drizzle, light S wind |
| 21–22 Aug. 1972 | 23 | overcast, NW wind 10–15 k |

killed in significantly greater numbers on non-overcast nights with southeasterly winds than on nights with other conditions (Table 3). Conversely, warblers were killed in significantly greater numbers on overcast nights. In the fall, losses at night during peak migration periods under the various conditions of cloud cover and wind direction were distributed in about the same frequency as the occurrence of nights with these conditions except for warblers and fringillids which were killed in significantly greater numbers on overcast nights with northeasterly winds.

The high proportion of fall losses on overcast nights within 12 h after the passage of a cold front is consistent with other published reports (Brewer and Ellis 1958, Tordoff and Mengel 1956, Laskey 1960, Taylor and Anderson 1973). The fall losses presented in Tables 2 and 3 were due primarily to the few, large, single-night kills (Table 1), each of which was preceded by a cold front through the LaMoure area.

TABLE 2

PERCENT OF LOSSES OCCURRING ON OVERCAST NIGHTS AT THE OMEGA TOWER IN 1972 AND 1973

| Family or group | Spring[1] (%) | Number of birds | Fall (%) | Number of birds |
|---|---|---|---|---|
| Rallidae | 35 | 34 | 41* | 22 |
| Other non-passerines | 36 | 11 | 50 | 10 |
| Parulidae | 64* | 44 | 81* | 135 |
| Fringillidae | 32 | 104 | 64* | 100 |
| Other passerines | 48 | 57 | 70 | 46 |
| Total | 42 | 250 | 70 | 313 |
| Percent of overcast nights | 32 | | 22 | |

[1] * Indicates statistical significance between % of loss and % of overcast nights.

TABLE 3

PERCENT LOSSES IN RELATION TO CLOUD COVER AND WIND DIRECTION AT THE OMEGA TOWER IN THE PEAK MIGRATION PERIODS IN 1972 AND 1973

| Family | Cloud cover[1] | Surface wind quadrant[2] NW 286–015° | NE 016–105° | SE 106–195° | SW 196–285° | No. of birds and (nights) |
|---|---|---|---|---|---|---|
| *Spring* | | | | | | |
| Rallidae | o | 20(27)[3] | 40(39) | 40(23) | 0(12) | 5(26) |
| | n | 29(42) | 12(16) | 53(24) * | 6(18) | 17(55) |
| Parulidae | o | 32(15) | 0(23) | 59(54) * | 9( 8) | 22(13) |
| | n | 20(47) | 0(14) | 50(25) | 30(14) | 10(36) |
| Fringillidae | o | 21(15) | 21(35) | 57(40) | 0(10) | 28(20) |
| | n | 3(43) | 16(18) | 68(27) * | 13(12) | 62(49) |
| *Fall* | | | | | | |
| Rallidae | o | 33(38) | 67(31) | 0(13) | 0(19) | 3(16) |
| | n | 11(24) | 11(20) | 33(26) | 44(30) | 9(66) |
| Parulidae | o | 23(13) | 70(50) * | 3(13) | 4(25) | 69( 8) |
| | n | 37(23) | 21(27) | 16(17) | 26(33) | 19(30) |
| Fringillidae | o | 2(24) | 91(24) * | 2(29) | 6(24) | 54(17) |
| | n | 20(24) | 5(10) | 10(27) | 65(39) | 20(41) |

[1] o = overcast, n = non-overcast.
[2] * Indicates statistical significance between % of loss and % of nights with indicated weather conditions.
[3] % of nights in each wind category are in parentheses.

Spring losses were not characterized by large kills but were smaller and more evenly distributed throughout the season. There was no direct association of spring losses with frontal movements: the bulk of the losses occurred on nights with favorable (i.e. southeasterly) winds. Ceilometer observations made at the tower revealed that the bulk of spring migration took place on nights with southeasterly winds.

The percent of losses of birds recovered within various distances of the tower varied with cloud cover (Table 4). In each family or group the percent killed in stratum A on overcast nights was similar to that on non-overcast nights. Among rails and other non-passerines, the losses on non-overcast nights were distributed approximately evenly among the 4 strata. Losses to passerines on non-overcast nights consistently exceeded those on overcast nights in strata C and D. In each family or group, losses on non-overcast nights in stratum D were 3 or 4 times those on overcast nights. Non-passerines suffered substantially greater losses in the outermost stratum than did passerines, particularly on non-overcast nights. Overall, losses on overcast nights were concentrated near the tower in strata A and B, whereas losses on non-overcast nights were more evenly distributed, 9% occurring at least 184 m

TABLE 4
PERCENT OF LOSSES BY STRATUM AT THE OMEGA TOWER ON OVERCAST AND NON-OVERCAST NIGHTS IN THE 1972 AND 1973 MIGRATION SEASONS

| Family or group[1] | Cloud cover[2] | Percent by stratum A | B | C | D | Number of birds |
|---|---|---|---|---|---|---|
| Rallidae | o | 23 | 36 | 36 | 5 | 21 |
| | n | 22 | 28 | 28 | 22 | 35 |
| Other non-passerines | o | 43 | 21 | 29 | 7 | 9 |
| | n | 31 | 19 | 25 | 25 | 12 |
| Parulidae* | o | 44 | 43 | 13 | 1 | 137 |
| | n | 50 | 20 | 26 | 4 | 42 |
| Fringillidae* | o | 29 | 46 | 23 | 2 | 97 |
| | n | 30 | 35 | 28 | 8 | 107 |
| Other passerines | o | 34 | 38 | 27 | 2 | 59 |
| | n | 25 | 41 | 28 | 6 | 44 |
| All birds* | o | 36 | 42 | 20 | 2 | 323 |
| | n | 31 | 32 | 27 | 9 | 240 |

[1] * Indicates statistical significance between overcast and non-overcast nights.
[2] o = overcast, n = non-overcast.

from the tower. Within warblers, finches, and total birds, the distribution of kill by strata on overcast nights differed significantly from that on non-overcast nights.

Table 5 shows how the distance of kills from the tower varied with cloud cover and season. In both spring and fall, greater percentages of the seasonal losses were generally found in the 2 innermost strata under overcast conditions than under non-overcast. Conversely, in strata C and D, relatively more birds were found dead following non-overcast nights in both spring and fall than following overcast nights. When mortality between seasons is compared, spring losses were generally less than fall losses in strata A and B but exceeded the fall losses in strata C and D on both overcast and non-overcast nights. In both spring and fall, the differences in mortality between overcast and non-overcast nights within the strata were statistically significant and indicate that the distance of losses from the tower was influenced by cloud cover.

The differences in location of tower casualties in spring and fall is depicted in Fig. 1. This graph includes all of the tower casualties found in 1972 and 1973 and consists of raw data uncorrected for differences in areas searched. It shows that in each year the percent of fall losses exceeded those of spring within 92 m of the tower. Beyond 92 m the situation was reversed,

TABLE 5
PERCENT OF LOSSES BY STRATUM AT THE OMEGA TOWER ON OVERCAST AND NON-OVERCAST NIGHTS IN 1972 AND 1973

| Season[1] | Cloud cover[2] | Percent by stratum | | | | Number of birds |
|---|---|---|---|---|---|---|
| | | A | B | C | D | |
| Spring* | o | 34 | 34 | 28 | 4 | 104 |
| | n | 26 | 32 | 30 | 12 | 146 |
| Fall* | o | 37 | 45 | 17 | 1 | 219 |
| | n | 40 | 31 | 23 | 6 | 94 |

[1] * Indicates statistical significance in % of losses by strata between overcast and non-overcast nights.
[2] o = overcast, n = non-overcast.

except for the 184–229 m interval in 1972. These results, although not statistically significant in 1973, show that, except for this one exception, larger spring losses consistently occurred at greater distances from the tower than did fall losses.

Cloud conditions seem to have a considerable effect on the manner in which bird mortality actually occurs at the Omega tower. From the results obtained it appears that most fall mortality takes place when large numbers of birds are aloft on overcast nights. Such nights are usually closely associated with the passage of a cold front. On overcast nights, migrants congregate around the tower (Avery et al. 1976) and are killed near the structure by colliding with it, the guy wires and transmitting cables, or other birds. On the other hand, spring migrants are apparently aloft when winds are favorable, regardless of cloud cover (Table 3), and thus much mortality occurs on non-overcast nights when migrants are not congregated at the tower. On such nights, migrants actually seem to avoid the structure (Avery et al. 1976). Consequently, in the spring, sizable losses occur on non-overcast nights far from the central structure through collisions with outlying guy wires and the transmitting cables.

The regular occurrence of substantial bird losses on non-overcast nights is perhaps peculiar to the Omega tower with its widespread system of cables. Losses do occur on non-overcast nights at other towers with less extensive cable arrays (e.g. Stoddard and Norris 1967), but apparently they are not as great as at the Omega tower. Birds deviating from their flight path to avoid most towers may remove themselves from the danger of the supporting guy wires. The 16 transmitting cables extending from the top of the Omega tower, however, pose additional problems; and birds avoiding the tower, and hence the innermost supporting guy wires, are still liable to collide with the outer transmitting cables.

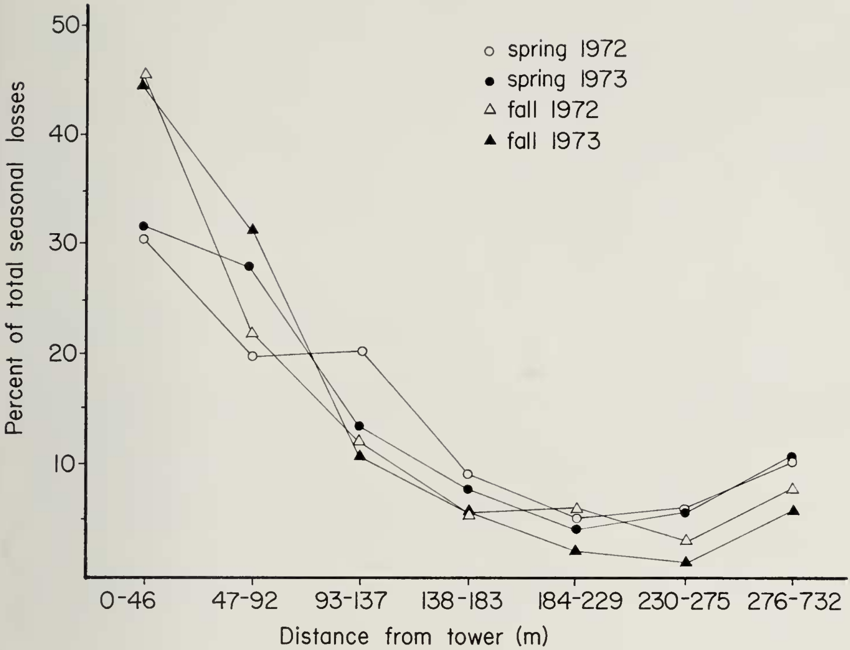


FIG. 1. The % of total seasonal losses collected at 46-m intervals from the Omega tower in 1972 and 1973.

Some of the differences in mortality among groups of migrants may be due to interspecific (or interfamilial) behavioral differences. For instance, at the Omega tower, warblers were prone to be killed close to the central structure (Table 4). Possibly warblers are influenced by red tower lights more so than are other groups, or perhaps warblers are less able to change direction to avoid inner guy wires than are other migrants. The sizable proportions of some kinds of non-passerines killed away from the tower, especially on non-overcast nights (Table 4), suggests behavioral differences that may be even more basic than family or group-level differences.

Overing (1936, 1937) also noted differences in the responses of various passerines to tall, lighted structures. On 20 October 1935, hundreds of Field Sparrows, *Spizella pusilla*, perched on benches at the base of the lighted Washington Monument; "None of these sparrows struck the monument that night, nor did they seem confused by the lights nor fly against the shaft, as the vireos and warblers were doing." The following fall, there was a similar occurrence. Of the 523 birds collected by Overing in the falls of 1935 and 1936, only 7 were fringillids. Further differences are suggested by Stoddard and Norris (1967) who noticed that during nights of heavy rainfall, fringillids tended to persist in their migratory flight while warblers, vireos, and thrushes sought ground cover.

No experimental evidence exists detailing differences among various taxa of nocturnal migrants in their response to tall, lighted structures. This area warrants more attention because conceivably such an investigation could lead to methods whereby losses of some species at towers can be reduced.

## SUMMARY

An examination of the cloud cover and wind conditions that accompanied bird losses at a 366-m tower in southeastern North Dakota revealed that most fall losses occurred under overcast skies associated with the passage of cold fronts. In the spring, 58% of the mortality took place on non-overcast nights, generally with southeasterly winds. Rails were killed in relatively equal proportions on overcast and non-overcast nights in both spring and fall. Warblers were killed in significantly greater numbers on overcast nights in both seasons, as were fringillids in the fall. Losses on non-overcast nights tended to be distributed farther from the tower than were those on overcast nights. Fall losses were concentrated closer to the tower than were spring losses because fall losses occurred mostly under overcast skies as migrants milled about the tower. Spring losses seemed to occur primarily on non-overcast nights through collisions with outlying guy wires and the transmitting cables. Behavioral differences among species or families of migrants may be involved in migrant mortality at towers.

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